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SOLAR RADIATION OBSERVATIONS AT APIA, SAMOA

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[Apia Observatory, Samoa, May 19, 1927]

The Apia Observatory purchased a Gorczyński pyrheliometer in 1924 in order to carry on a series of measurements on the amount of solar radiation transmitted by the humid atmosphere of this Tropic island (long. 171° 46′ W. lat. 13° 48′ S.).

The pyrheliometer had been previously calibrated by Dr. H. H. Kimball with the United States Weather Bureau standard and found in good agreement with it. (1) There has been no opportunity to recalibrate since that time, but two facts indicate that the constants of the pyrheliometer, if carefully handled, do not change over considerable periods. (1) This instrument had been calibrated in Europe several years prior to the Washington calibration and after a strenuous expedition to Tougourt in the Sahara Desert had retained its accuracy, as shown by the Washington calibration, to an accuracy of 1 per cent. (2) The recorded values in 1927 are practically the same as those taken at the same season of the year 1925.

The base to which the thermopile was attached was rigidly fastened to a post in the center of a small platform erected on the seashore. The thermopile was about 2 m. above mean sea level. It was connected by 33.5 m. of the 16-gauge copper wire to the recording millivoltmeter in the main office. The exposure was good, but since the equatorial mounting had been made for the Northern Hemisphere the base had to be placed vertical instead of horizontal, causing a greater strain on the driving gear than that for which it had been designed. Probably on this account the driving clock did not keep the thermopile facing directly into the sunlight without frequent readjustment. Between the hours of 8 a. m. and 4 p. m. the instrument was carefully watched. The values of the solar radiation for air masses greater than 2 may be too small due to the thermopile not being properly oriented.

A table was prepared giving for each day of the year the instant when the air mass was 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, etc. Using this table, the records of the millivoltmeter were measured and the values at the times given in the table were tabulated. In the case of obvious irregularities in the record caused either by clouds or the thermopile having got out of line, a smooth curve was drawn through the dots when registration was satisfactory and the tabulated values derived therefrom. The present investigation includes only those days in which there were at least four hours' good record. Since rain squalls and overcast skies are of very frequent occurrence during the months November to March, the data for these months are rather scanty.

In Samoa the year may be divided into three seasons—*wet season* (November–February), 51 per cent rainfall, trade winds irregular; *equinoctial* (March–April, September–October), 33 per cent rainfall; beginning and end of trade-wind season; *dry season* (May–August), 16 per cent rainfall, trade winds strongly developed. During the dry season the solar radiation is approximately constant (1.1 gm. cal.) from 9 a. m. to 3 p. m. At the other seasons of the year this period of constant solar radiation is longer because the sun is farther south and remains at high altitudes for a longer period of the day.

In Table 1 under Q is given the observed solar radiation. This shows that in the wet season the radiation is more intense than in the dry season, and that when morning and afternoon values of radiation passing through

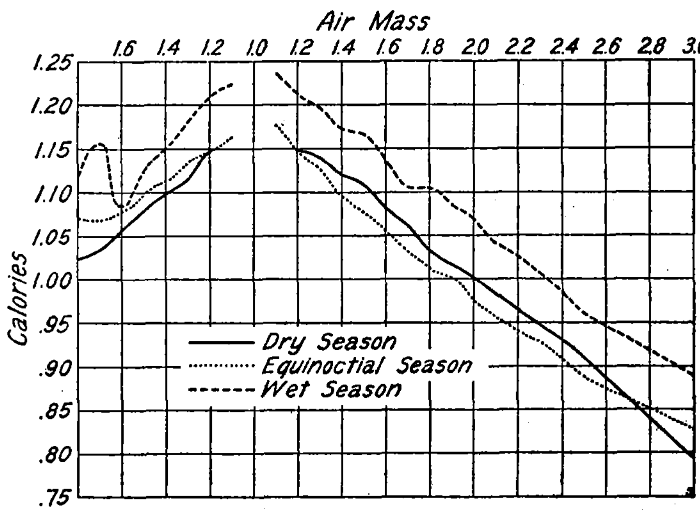

FIG. 1.—Solar radiation intensity, sat normal incidence, reduced to mean distance of the earth from the sun. (Gram-calories per minute per square centimeter)

the same air mass are compared during the wet and dry seasons the afternoon values are the greater, but in the equinoctial months the morning values are the greater.

During the dry season the earth is at a greater distance from the sun than in the wet season, so that before comparing the transparency of the atmosphere it is necessary to adjust the values of Q to unit distance. The dry season values were multiplied by 1.028, the wet season by 0.973, and the equinoctial values were unchanged. As shown by the values of Q' in Table 1 and Figure 1, the radiation values are uniformly higher in the wet season.

TABLE 1.—*Summary of solar radiation observations at Apia, Samoa*

[Q = measured radiation intensity and Q' = the intensity reduced to mean distance of the earth from the sun, expressed in gram-calories per minute per square centimeter; a = atmospheric transmission coefficient]

Air mass	Dry season				Equinoctial season				Wet season				Year	
	No. obs.	Q	Q'	a	No. obs.	Q	Q'	a	No. obs.	Q	Q'	a	No. obs.	Q
A. M.		*cal.*	*cal.*			*cal.*	*cal.*			*cal.*	*cal.*			*cal.*
1.8	19	0.996	1.024	.7015	6	1.071	1.071	.7193	3	1.151	1.120	.7372	28	1.073
1.7	20	1.007	1.035	.6913	11	1.069	1.069	.7047	5	1.188	1.156	.7379	36	1.088
1.6	21	1.028	1.057	.6846	14	1.078	1.078	.6931	8	1.115	1.085	.6958	43	1.074
1.5	23	1.021	1.080	.6641	16	1.099	1.099	.6850	12	1.156	1.125	.6958	51	1.092
1.4	26	1.067	1.097	.6660	19	1.112	1.112	.6703	14	1.182	1.150	.6888	58	1.120
1.3	24	1.085	1.115	.6536	19	1.135	1.135	.6625	14	1.214	1.181	.6786	57	1.145
1.2	8	1.117	1.148	.6463	19	1.147	1.147	.6460	14	1.244	1.210	.6753	41	1.169
1.1	----	------	------	-----	18	1.163	1.163	.6386	15	1.258	1.224	.6584	33	1.210
P. M.														
1.1	----	------	------	-----	21	1.177	1.177	.6355	14	1.271	1.237	.6648	35	1.224
1.2	8	1.117	1.148	.6463	24	1.147	1.147	.6460	15	1.246	1.212	.6762	47	1.170
1.3	25	1.107	1.140	.6516	24	1.122	1.122	.6555	16	1.230	1.197	.6902	65	1.153
1.4	26	1.090	1.120	.6761	24	1.096	1.096	.6654	16	1.207	1.174	.6914	66	1.131
1.5	26	1.069	1.109	.6850	24	1.076	1.076	.6755	15	1.198	1.166	.7127	65	1.114
1.6	26	1.051	1.080	.6922	24	1.055	1.055	.6837	15	1.170	1.138	.7168	65	1.092
1.7	26	1.032	1.061	.7016	24	1.032	1.032	.6902	15	1.136	1.105	.7186	65	1.067
1.8	26	1.005	1.033	.7050	24	1.012	1.012	.6970	14	1.136	1.105	.7451	64	1.051
1.9	26	0.991	1.017	.7122	23	1.003	1.003	.7070	13	1.115	1.085	.7440	62	1.036
2.0	26	0.975	1.002	.7191	22	0.975	0.975	.7088	13	1.099	1.069	.7423	61	1.016
2.1	26	0.957	0.984	.7241	22	0.957	0.957	.7145	13	1.071	1.042	.7442	61	0.995
2.2	26	0.941	0.967	.7281	22	0.941	0.941	.7200	13	1.055	1.027	.7494	61	0.979
2.3	26	0.922	0.948	.7295	21	0.929	0.929	.7263	13	1.035	1.007	.7551	60	0.962
2.4	26	0.906	0.931	.7367	21	0.909	0.909	.7291	13	1.014	0.987	.7549	60	0.943
2.5	26	0.886	0.911	.7393	21	0.888	0.888	.7318	13	0.993	0.966	.7562	60	0.922
3.0	23	0.774	0.796	.7433	19	0.828	0.828	.7532	11	0.915	0.890	.7716	53	0.839
4.0	20	0.668	0.687	.7720	15	0.737	0.737	.7852	6	0.880	0.856	.8151	41	0.762
5.0	19	0.556	0.572	.7834	14	0.618	0.618	.7956	5	0.839	0.816	.8412	38	0.671

The transmission of the atmosphere was determined from the Bouguer-Langley formula $i = Ia^m$

where i = observed solar radiation.
I = solar constant assumed value 1.938.
m = air mass.
a = transmission coefficient as given in Table 1.

This formula is strictly correct for monochromatic radiation only, and for that reason the value of a varies with m.

In both the dry and the wet seasons the afternoon values of the transmission coefficient (see fig. 2) are

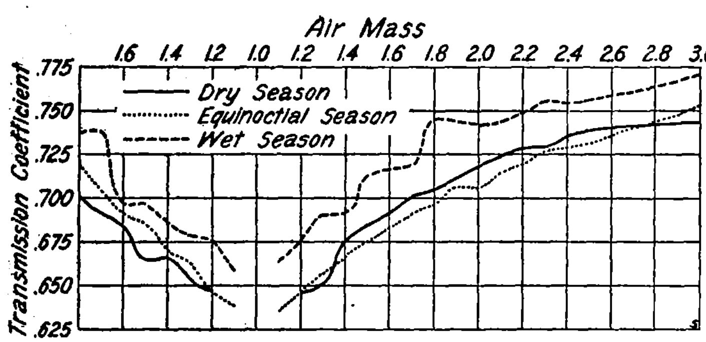

FIG. 2.—Atmospheric transmission of solar radiation, a ($i = Ia^m$)

greater than the morning, while in the equinoctial months it is greater in the morning. This latter condition might have been expected to persist throughout the year, as the absolute humidity is less in the morning hours than in the afternoon.

The observations were necessarily taken on clear days, so that the data given by O. Tetens and F. Linke **(2)** for absolute humidity on bright (heitere) days may be considered as applying very closely to those days on which the pyrheliometer records were obtained. Fowle's formula (that the depth of water in cm. equals 0.23 × absolute humidity in mm.) has been used to compute the precipitable water content of the air based on the bright days of the year.

TABLE 2.—*Humidity and moisture content on bright days, Apia, Samoa*

Local time	8h–9h	9h–10h	10h–11h	11h–12h	12h–13h	13h–14h	14h–15h	15h–16h	16h–17h
Approximate air mass:									
January	1.9–1.4	1.4–1.1	1.1	-----	-----	-----	-----	-----	-----
June	2.8–1.8	1.8–1.4	1.4–1.3	1.3–1.3	1.3	-----	-----	-----	-----
Absolute humidity	19.1	19.8	21.0	21.2	22.4	22.4	21.8	22.2	21.8
Moisture content	4.39	4.55	4.83	4.88	5.15	5.15	5.01	5.11	5.01

It has been pointed out by H. H. Kimball that the value derived from an extension of Fowle's curves for the transparency coefficient of air with the same water content as found at Apia, Samoa, is in practical agreement with that observed during the wet season at Apia. During the dry and equinoctial seasons the observed transparencies were less than could be accounted for by the water vapour alone. This may be due to two causes: (1) The salt particles in the air such as Owen has found in the North Atlantic may be increased in the dry season. In the wet season these particles are dissolved. The transparency for visual rays is certainly better immediately after a rain shower when on many occasions the light and dark areas on the mountainside of Savaii, 60 km. distant, are easily discernible. This is never the case after three or four days without rain. Since the seeing is almost entirely over water and adjacent land areas are relatively small the haziness is not due to dust particles. (2) The trade winds have been shown by pilot-balloon observations to reach greater heights in the dry than in the wet season. The trade winds are much more laden with moisture than the antitrades above them. From kite observations F. Linke **(3)** gives the following data as typical.

Height	Relative humidity	Wind
Meters	*Per cent*	
0	65	E. S. E.
1,300	90	
2,800	6	E. to E. N. E

F. Linke **(4)** found notably higher values for the solar radiation in Southeast trade wind in the Atlantic than those here given for Apia, which may be considered as typical of conditions in the Southeast trade wind area in the Pacific. For an air mass 1 at sea level and with approximately the same absolute humidity Linke gives a value of 1.464 gm. cal. to be compared with 1.21 gm. cal. at Apia. It is doubtful if this difference may be entirely accounted for by instrumental error but must be ascribed, in part, to better transmission of radiation over the South Atlantic than the South Pacific.

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